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Technology Acceptance of 3D Technologies among Practical Nursing Students: A Mixed-Methods Study

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ABSTRACT

In the future, health care education will face challenges to adapt to multiple technological tools in teaching and learning. The aim of this study was to describe practical nursing students' technology acceptance and possible change therein after implementing three-dimensional (3D) technology during a first aid course in the level of vocational education and training in Finland. In this qualitative dominant mixed method study, students used 3D images, 3D environments, and 3D printing during their first aid course. Students answered pre- (n = 30) and post-surveys (n = 28) and, after one month from the first aid course, participated in focus group interviews (n = 30) based on the theoretical framework of the Technology Acceptance Model (TAM). The data was analysed by means of descriptive statistical analysis and qualitative content analysis. As a result, students' technology acceptance was positively oriented. Five main qualitative categories

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were identified: 1) Usefulness for education, 2) Usefulness for care work, 3) Benefits for individual role, 4) Preparedness for future technological solutions, and 5) Challenges with technological solutions. In addition, the quantitative results, although exploratory, indicated statistically significant changes in students' technology acceptance. As a conclusion, the students reported that using 3D technology in practical nursing education may enhance their technology acceptance. They also stated that it may also prepare them to be more technologically oriented in working life. The promising elements of 3D technology can be taken into consideration when health care educators are planning their teaching.

Keywords: 3D Technology; Technology Acceptance Model; Practical Nursing Education; Mixed Methods

1. Introduction

The educational context in European healthcare education varies, although shared frameworks exist[1]. The field also faces future challenges regarding technological solutions and their integration into actual teaching practices[2]. Teachers have an opportunity to rethink their pedagogical approaches and not only focus on subject-specific content but also foster students' ability to engage creatively with technological tools[3–5].

In practice, educational development requires consideration of several perspectives[6]. First, students' engagement and active participation can be enhanced through innovative and creative teaching tools or methods[7, 8]. Second, the development of students' computational thinking should be meaningfully connected to innovative teaching practices[9–11]. Third, technological solutions must be pedagogically valid and meet students' learning needs[12]. Addressing these challenges requires adequately researched knowledge about the possibilities offered by such technologies[5].

Three-dimensional (3D) technology is one promising tool for healthcare education[2, 13, 14], although research in this area remains relatively limited[15] compared to its application in medical education[13, 16]. In healthcare education, 3D technology has been associated with increased learning motivation[17] and improved learning outcomes[18]. Benham and San[19] also link 3D technology to students' technology acceptance in occupational therapy education, emphasizing its role in developing technological thinking. However, existing studies have primarily focused on higher education, and research on its use in practical nursing education is scarce[15].

The main aim of the present study is to describe practical nursing students' perspectives in vocational education about their technology acceptance when innovative and creative teaching is implemented using 3D technology in a first aid course. This research seeks to provide teachers with insights and ideas for adopting more technologically oriented teaching approaches.

2. Materials and Methods

2.1. Design and Research Questions

The study design was mixed methods with qualitative dominance[20]. Two research questions guided this research, as follows:

1. How do practical nursing students self-assess their technology acceptance towards 3D technology changes after using 3D technology during the first aid course?
2. How do practical nursing students describe their technology acceptance towards 3D technology after using 3D technology in the first aid course?

2.2. Three-Dimensional Technology

3D technology is commonly defined as utilising three individual dimensions, including varied levels of interaction with the user, for example, with mobile devices or with glasses and haptic devices[21]. Overall, the technological solutions in the concept of 3D technology can be multiple[13, 15, 21]. Basically, this refers to 3D images[22], 3D environments[23], 3D holograms[24], and 3D printing[25, 26].

2.3. Context of the First Aid Course

This study was implemented with two groups of first-year practical nursing students. Both groups were in the same phase of their studies. These groups were selected because the timing for the first aid course was identical for both groups. Both groups intended the first aid course with the same learning aims, as guided by the Finnish National Board of Education[27]. The duration of the first aid course was 16 hours (two consecutive days) with the same teachers. All practical nursing students got a first aid course that included the following 3D technologies: 3D images, 3D environment, and 3D printing (**Table 1**).

Table 1. Description of Different 3D Technologies Used during the First-Aid Course.

The Learning Aims for Students	3D Technology and Modifying Process	How 3D Technology Was Implemented?
Learn how to give first aid during different sudden attacks (for example, cerebrovascular accidents).	3D images Three hours	Students used a television with interactive 3D images of different organs, which discussed sudden attacks.
Learn how to give first aid in traffic accidents and sudden attacks (for example convulsion). Learn how to give wound care.	3D environment (360° environment) Four hours	Students used different 360° environments with tablets or mobile phones and reflected each content.
Learn how to resuscitate. Learn how to give first aid to unconscious people and in shock.	3D environment (360° environment) Four hours	Students moved ahead in a 3D environment and faced different cases. After using the 3D environment, they reflected immediately on what they experienced.
Learn how to give first aid for a heart attack.	3D environment (augmented reality) Two hours	Students used glasses to experience heart structure and what happens during a heart attack.
Learn how to give first aid in bone fractures and strains.	3D printing Three hours	Students had different kinds of 3D-printed objects (for example, 3D-printed patella with fracture) with guidance in discussing them. Printer was also printing during the course.

2.4. Theoretical Framework

The theoretical framework of this research is based on the Technology Acceptance Model (TAM) and its extended version[28, 29]. TAM originally focuses on two key elements: perceived usefulness and perceived ease of use[28]. Perceived usefulness refers to an individual's belief that a system or technology will enhance their job performance or relevance[28, 29]; for example, how effectively the individual can utilize the outcomes of a new technological solution[29]. Perceived ease of use means that the simpler a system or technology is to operate, the more likely individuals are to adopt it with a positive attitude[28] and, importantly, to use it voluntarily[29].

In the extended version, TAM2, Venkatesh and Davis[29] incorporate two additional dimensions: social influence processes (image, voluntariness, and subjective norm) and cognitive instrumental processes (job relevance, perceived ease of use, result demonstrability, and output quality). For the present research, TAM offers a widely applied theoretical framework[30], particularly for a topic that is relatively rare in practical nursing education[31]. Furthermore, TAM is adaptable to different user contexts, including variations in perceived technology[32]. It has also been extensively employed as a theoretical foundation in educational research[30].

2.5. Population and Sample

The study was conducted in one of Finland's largest vocational institutes for health and welfare, selected because it serves a wide geographical area and offers comprehensive programs. The Finnish vocational education system is regulated by the Vocational Education and Training Act[33] and overseen by the National Board of Education, which sets guidelines for vocational qualifications in social and healthcare. Admission to these programs requires completion of at least lower secondary education.

Practical nursing studies typically last two to three years, comprising a total of 180 competence points in accordance with the European Credit System for Vocational Education and Training (ECVET), where one competence point equals a minimum of twelve hours of study. The curriculum includes two compulsory qualification units[27]: (1) Promoting Growth and Participation (25 competence points) and (2) Promoting Wellbeing and Functional Capacity (30 competence points). Each unit integrates practical training in real work environments. After completing these units, students will choose their specialization [27]. Upon completion of all studies, graduates must register with the National Supervisory Authority for Welfare and Health [34] to become licensed practical nurses.

In this study, the learning context was the first-aid course (one ECVET point), which is part of the qualification unit Promoting Wellbeing and Functional Capacity [27].

In total, 32 practical nursing students were invited to take part in the study. Group one included 13 (n = 13) and group two 19 (n = 19) practical nursing students. The sample size was evaluated as sufficient because of the underlining study's qualitative dominance. The inclusion criteria were the following: (1) first-year practical nursing student, and (2) students' former competence in first aid had been evaluated by the teacher from the vocational institute, and the competence was not sufficient to transfer to competence points.

Participants' personal data—for example, age or gender—was not collected, because it was considered irrelevant to the aim of the study [35].

All students were at the same phase in their studies. They also had the same amount of competence points. Moreover, they were all in the basic studies meaning that the specialization (for example, in mental health) had not begun. The sample was recruited from those groups whose curriculum made it possible to have all the necessary 3D technology equipment available for use. The informed consents were given to the students after the general information about the research.

2.6. Ethical Consideration

The study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Ethics Committee of the University of Turku (34/21, 22.11.2021).

2.7. Data Collection

Data were collected through pre- and post-course surveys (TAM2) and focus group interviews between January and May 2022 from practical nursing students (n = 32) at one vocational institute. At the start of the first-aid course, two students (n = 2) were absent. Each student who participated in the survey (pre- and/or post) also participated in the focus group also (**Figure 1**).

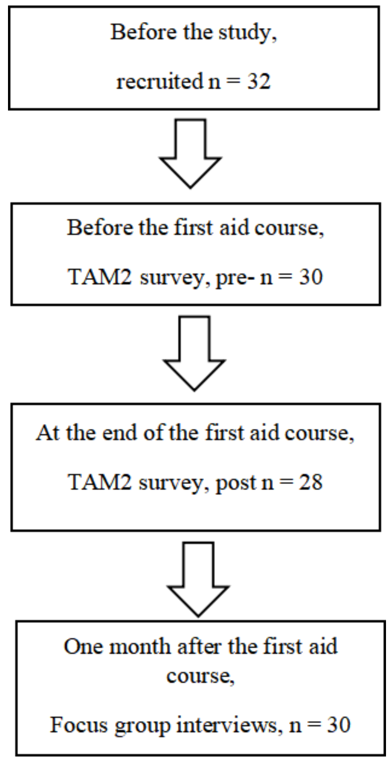

Figure 1. Description of the Data Collection.

The survey (presented in **Supplementary Materials**) employed the extended Technology Acceptance Model questionnaire (TAM2), a Likert-scale instrument (1 = strongly disagree to 7 = strongly agree) comprising nine categories: intention to use, perceived usefulness, perceived ease of use, subjective norm, voluntariness, image, job relevance, output quality, and result demonstrability [29]. After obtaining licensed permission from the developer and publisher, the questionnaire was back-translated into Finnish and tested with 15 practical nursing students (n = 15) [36]. Testing occurred at the beginning of the school day, and participation was voluntary. The purpose of this pilot was solely to improve the questionnaire's comprehensibility. Following completion, students provided oral feedback, which the researcher documented. Based on this feedback and the context of 3D technology, minor revisions were made to sentence structures and terminology—for example, clarifying the concept of subjective norm to mean the subjective experience of their own (practical nursing students), not, for example, the professional practical nurses. The revised questionnaire was then reviewed by the same students to confirm the appropriateness of changes before final implementation. There were no statistical tests in the questionnaire in the pilot phase.

Surveys were completed anonymously, with each student using an individual code to ensure data comparability. The research team did not have access to the identity behind each code. Surveys were administered at the beginning of the course (n = 30) and at its conclusion (n = 28).

Focus group interviews were conducted one month after the first aid course. The main author (MA) conducted the interviews. The interviewer had a background as a registered nurse and an educator in practical nursing education; however, not with participants in this study. In addition, the main author also has a scientific education. During the interviews, the main author kept a reflective journal (e.g., a diary) to maintain as much objectivity as possible throughout all sessions. The Technology Acceptance Model also guided the focus group interviews, which concentrated on three scales: perceived usefulness, perceived ease of use, and job relevance [29]. The interviews aimed, first, to capture diverse perspectives on technology acceptance [37, 38], and second, to facilitate discussion by creating a supportive group environment [39]. Thirty students participated, divided into five focus groups of five to seven members each. All interviews were conducted face-to-face at the vocational institute, recorded, and lasted 20–30 min. Prior to each session, students were informed that participation involved no additional schoolwork and that there was no urgency to foster a safe and comfortable environment. The interviewer, who had no prior personal relationship with the students, used a printed version of the theoretical framework and guiding questions to ensure discussions remained relevant to the research topic.

2.8. Data Analysis

In this study, the data analysis was conducted first separately (quantitative and qualitative findings). Secondly, the integration of TAM2-based quantitative results with qualitative findings was guided by a convergent mixed methods approach, and it was conducted using a joint display method, presented in the **Supplementary Materials** [40]. The purpose of the quantitative strand was not to test causal relationships but to offer structured indicators that could be meaningfully integrated with the qualitative results in the convergent design. The joint display served as the primary mechanism for integration, enabling category-by-category examination of convergence, complementarity, and divergence across data sources. It is also meaningful to notice that quantitative results are exploratory and there has been no power analysis in this study, which reflects that the quantitative results should be interpreted as indicative rather than conclusive.

The complete quantitative data analysis was performed with the statistical software SAS Enterprise Guide 7.1. The final analysis included 28 participants, as two were absent during the post-questionnaire and therefore excluded from paired comparisons. The internal consistency of the items was analysed with Cronbach's alpha and its confidence interval, together with inter-item correlations, in order to see if the items within a category formed a reliable instrument and if a sum variable out of the items by category could be calculated. The TAM2 categories were used as theoretically grounded constructs; however, given the small sample and the contextual adaptation of items, construct validity should be interpreted with caution. The normality of the difference between the category means from the post-questionnaire to pre-questionnaire was inferred from the plot review and from significant key statistical figures, including the p-value of the Shapiro-Wilk test for normality.

The categories were analysed separately to determine if there were any statistically significant differences between the students' post- and pre-questionnaire answers. A Paired Sample t-test and Wilcoxon Signed-Rank Test were used to compare the means of the two dependent measurements taken from the same student. Given nine paired comparisons, the risk of Type I error was considered. No formal correction was applied due to the exploratory nature of the study and the small sample size, but p-values should be interpreted cautiously.

During the internal consistency analysis of the "Result demonstrability" category items, one statement was dropped due to its negative correlation with the total category and with all other items within the group, thus significantly lowering the scale's Cronbach's Alpha. Deleting this question raised Cronbach's Alpha back to an acceptable level (from 0.52 to 0.79).

The sum variable was then calculated out of the items by each category and time point as the mean of the item's overall sum by category. To determine the test to be used in the statistical analysis of the comparison of means from two dependent measurements, the difference between the sum variables from the post-questionnaire and pre-questionnaire was calculated and inferred by the nine categories. In five categories, the differences between measurement means were normally distributed, and a Paired Sample *t*-test can be used for analysis ("Perceived ease of use", "Image", "Job relevance", "Output quality", and "Result demonstrability"). In four categories, the differences between measurement means were not normally distributed, and a nonparametric Wilcoxon Signed-Rank Test should be used for the statistical analysis ("Intention to use", "Perceived usefulness", "Subjective norm", "Voluntariness"). Normality was inferred from plot review and from significant key statistical figures, including the *p*-value of the Shapiro-Wilk test for normality with a significance level of 0.05. To ensure analytical transparency, all analytical decisions—including item removal, test selection, and handling of attrition—are fully reported (**Table 2**).

Table 2. Reliability, Normality of Difference between the Categories from Post- to Pre-Measurement.

	Reliability		Normality
Category	**Cronbach Alpha (95%-Confidence Interval)**	**Range of Pearson Correlation between Items**	**Shapiro-Wilk *p*-Value of the Difference between Post-Mean and Pre-Mean**
1. Intention to use	0.886 (0.81;0.93)	0.80	0.027
2. Perceived usefulness	0.775 (0.66;0.86)	0.24–0.65	0.027
3. Perceived ease of use	0.875 (0.81;0.92)	0.52–0.74	0.055
4. Subjective norm	0.909 (0.85;0.95)	0.83	0.002
5. Voluntariness	0.805 (0.70;0.88)	0.48–0.64	<0.001
6. Image	0.794 (0.68;0.87)	0.37–0.76	0.315
7. Job relevance	0.862 (0.77;0.92)	0.76	0.873
8. Output quality	0.800 (0.66;0.88)	0.67	0.051
9. Result demonstrability	0.793 (0.68;0.87)	0.44–0.77	0.687

Focus group interviews were analyzed using theory-driven qualitative content analysis based on the TAM framework, following three phases: preparation, organization, and reporting [41, 42].

During the preparation phase, meaning units were identified according to the concept of technology acceptance [41, 43]. These meaning units corresponded to TAM categories: perceived usefulness, perceived ease of use, and job relevance [29, 41]. For example, all content related to perceived usefulness was grouped into one meaning unit.

In the organization phase, a categorization matrix was developed to guide the coding process [41]. The matrix was pre-tested prior to the final analysis to ensure consistent alignment with the theoretical framework throughout the process [41]. Based on the main data analysis, categories and subcategories were created in compliance with the Technology Acceptance Model [29, 41]. During the analysis, 8-10 different theory-driven codes were identified in each category, and possible disagreements of the codes were discussed among the research group.

Finally, in the reporting phase, all steps of the analysis were reviewed and validated by the research team before final reporting [41] (**Table 3**).

Table 3. The Example of Theory-Driven Content Analysis.

Meaning Unit under the Theoretical Category "Perceived Ease of Use"	Condensed Meaning Unit	Code	Subcategory	Main Category
"*When you use different technologies in school, you get the idea, that maybe these are not so difficult at all*."	The multiple experiences make it easier to use different technologies.	Self-confidence with technology.	Perceived self-confidence with multiple technological solutions.	Preparedness for future technological solutions.

In the integration phase of both results, the qualitative insights represented the dominant elements of the analysis, referring to the fact that this study aimed to describe the perspectives of the practical nursing students deeply. For example, even when the category job relevance did not show a statistically significant increase in the survey, focus group discussions highlighted students' perceptions of 3D technology as professionally useful, particularly in patient education and future work tasks. Conversely, categories with significant quantitative change, such as perceived ease of use, were reinforced by qualitative themes like "Preparedness for future technological solutions," indicating convergence between data sets[40].

3. Results

3.1. Quantitative Results

A statistically significant change was found in three categories' means with the Paired Sample *t*-test. A statistically significant mean improvement of 0.74 was found in "Perceived ease of use" ($p < 0.001$), 0.43 in "Output quality" ($p = 0.030$), and 0.69 in "Result demonstrability" ($p < 0.001$) between the pre- and post-test (**Table 4**).

A statistically significant change was found in three categories' medians with the Wilcoxon Signed-Rank test. A statistically significant medians improvement of 0.25 was found in "Intention to use" ($p = 0.004$), 0.25 in "Perceived usefulness" ($p = 0.017$), and 0.33 in "Voluntariness" ($p = 0.042$) between the pre- and post-test (**Table 4**).

3.2. Qualitative Results

After the theory-driven analysis, the following five main categories were created: (1) Usefulness for education, (2) Usefulness for care work, (3) Benefits for the individual role, (4) Preparedness for future technological solutions, and (5) Challenges with technological solutions (**Table 5**).

Table 4. The Development of Technology Acceptance after Using 3D Technology.

Paired Sample *t*-Test				
Category	**Descriptive**		**Model-Based *p*-Value (Paired Sample *t*-Test)**	**Difference between Means (95% CI) for Statistically Significant Models**
	Mean (SD) for Pre-Test	**Mean (SD) for Post-Test**		
3. Perceived ease of use	4.83 (1.04)	5.57 (0.99)	<0.001*	0.74 (0.40–1.08)
6. Image	4.06 (1.50)	3.83 (1.63)	0.471	
7. Job relevance	5.61 (1.16)	5.61 (1.17)	1.000	
8. Output quality	5.25 (0.97)	5.68 (0.95)	0.030*	0.43 (0.05–0.81)
9. Result demonstrability	4.88 (1.25)	5.57 (1.03)	<0.001*	0.69 (0.35–1.03)
Wilcoxon Signed-Ranks Test				
Category	**Descriptive**		**Model-Based *p*-Value (Wilcoxon Signed-Ranks Test)**	**Median of the Difference (95% CI) for Statistically Significant Models**
	Mean (SD) for Post-Test	**Mean (SD) for Pre-Test**		
1. Intention to use	5.71 (1.07)	6.38 (0.80)	0.004*	0.25 (0.0–1.0)
2. Perceived usefulness	5.71 (0.75)	6.09 (0.70)	0.017*	0.25 (0.0–0.5)
4. Subjective norm	3.54 (1.72)	3.61 (1.38)	0.442	
5. Voluntariness	4.94 (1.55)	5.46 (1.08)	0.042*	0.33 (0.0–1.0)

Note: * Statistically significant result.

Table 5. Technology Acceptance of the Practical Nurse Students towards 3D Technology.

Relation to TAM	**Main Category**	**Subcategory**	**Example**
Perceived usefulness	Usefulness for education	Development of professional skills and knowledge	"It (3D) would help us so much to understand things better comparing to now, when we are just reading prints" (focus group 5)
		Benefits for patient and relative guidance	"With these pictures (3D images), I mean, you could be able to more easily tell relatives what happens the inside patients and which organ is located where." (focus group 3)

Table 5. *Cont.*

Relation to TAM	Main Category	Subcategory	Example
Perceived usefulness and job relevance	Usefulness for care work	More time for patients	"If I knew how to use technology in working life, it wouldn't take so much time to learn it, while the learning time is away from the patients." (focus group 1)
		Benefits to activate elderly patients	"You could help dementia patients go back, for example, to some city (3D environment) they have been when they were young." (focus group 5)
Perceived usefulness and job relevance	Benefits for individual role	Easier to find a job	"If you knew how to use this kind of technology, it may give you an advantage in the working markets." (focus group 4)
		Multiple roles in working life	"I think that this technology (3D) would make it more clear to me, that working life could be more than just care work." (focus group 1)
Perceived ease of use and job relevance	Preparedness for future technological solutions	Perceived motivation to learn new technological solutions	"I thought and wished, that is there like courses, where you can concrete more deeply in all these solutions."(focus group 2)
		Perceived self-confidence with multiple technological solutions	"When you have tried different technologies in school, you discover that it is not so hard. I mean, when you face something new in working life, the first idea may not be that I am scared." (focus group 5)
Perceived ease of use and perceived usefulness.	Challenges with technological solutions	Negative feelings with technology	"It (3D environment) made me feel nauseous." (focus group 3)
		Difficulties in using technology	"I didn't understand how to use it, because it was so complicated (3D environment)." (focus group 1)

3.2.1. Usefulness for Education

The main category "Usefulness for education" included the following subcategories: "Development of professional skills and knowledge" and "Benefits for patient and relative guidance". Practical nursing students described several educational benefits of 3D technology. The benefits were connected to how much better the students felt that they would learn new things in their future work if the 3D technology could be utilised. Practical nursing students emphasised how important the new knowledge is in nursing, and with 3D technology, they felt that they could understand it more easily. The other educational benefit related to the idea of how technology could help is when, in future work, they will try to explain something to patients or relatives. They noted that with the 3D technology, e.g., some diseases could be easier to diagnose when they were able to concretely show how the body reacts to the disease. This could help patients and relatives more deeply understand the importance of guidance.

"*In anatomy, it might be much easier to learn about bones and muscles, while you really can see where they are and what they look like*" (student from focus group 2).

3.2.2. Usefulness for Care Work

The main category "Usefulness for care work" included the following subcategories: "More time for patients" and "Benefits to activate elderly patients". Practical nursing students noted that if 3D technology were utilised more in education, they would spend less time learning new technologies in future working life. This was related to the idea that practical nursing students would learn in school how to use and make 3D images, 3D environments, and 3D printing. With this knowledge, they could utilise 3D technology with the patients without so much time away from the latter. Practical nursing students also offered concrete ideas on how to utilise the 3D technology with older patients, such as the possibility to activate memories from history with

3D images or 3D environments. According to the practical nursing students, this would support the performance of the elderly patients.

"*3D environments could be used in, for example, in work orientation*" (student from focus group 3).

3.2.3. Benefits for the Individual Role

The main category, "Benefits for the individual role", included the following subcategories: "Easier to find a job" and "Multiple roles in working life". Practical nursing students emphasised the meaning of technological knowledge and competence. They noted that using 3D technology in education could increase technological competence on the part of students. This could help them find more interesting employment positions more easily. Practical nursing students believed that, in the future, individual technological understanding will be one dividing theme when practical nurses seek various jobs.

"*I think that the better you can use these [3D], the better the chances you'll have in the future*" (student from focus group 1).

3.2.4. Preparedness for Future Technological Solutions

The main category "Preparedness for future technological solutions" included the following subcategories: "Perceived motivation to learn new technological solutions" and "Perceived self-confidence with multiple technological solutions". Practical nursing students pointed out that using 3D technology increased their motivation towards various technologies and increased their preparation for the future. They highlighted the fact that there will be increasingly different technological solutions pivoted around nursing as time goes on. This means that the students should have a positive attitude and motivation towards all new technologies they will face. The practical nursing students also emphasised that they felt it was quite easy to use images, environments, and printing in the 3D format, though these were, fundamentally speaking, new things for them in the educational context. This ease increased their self-confidence towards confronting new technologies, and lowered the possible barriers to trying new ones.

"I kind of have the belief that in the future everything will go more and more to virtual like this, and I mean everything..." (student from focus group 2).

3.2.5. Challenges with Technological Solutions

The main category, "Challenges with technological solutions", included the following subcategories: "Negative feelings with technology" and "Difficulties in using technology". The practical nursing students noted challenges related to using 3D technology. Some of the students experienced nausea when using a 3D environment, and that experience was related to negative acceptance of the 3D technology. Some of the students also emphasised that it was difficult to use all 3D technological solutions and that the experience did not increase their motivation to welcome new technological solutions in future working life.

"*It was weird when you were going around in that house and tried to find the places....I mean, at that point it was hard and it got me feeling sick*" (student from focus group 5).

4. Discussion

The main finding of this mixed-method study is that practical nursing students' technology acceptance of 3D technology was generally positive. Students perceived 3D technology as a useful and relevant tool for their future professional roles. This aligns with previous research, which has consistently linked positive experiences with 3D technology to increased student satisfaction [44–46]. In some cases, enthusiasm toward 3D environments has even been described as "overflowing" [44]. However, it is notable to understand that these elements (e.g., technology acceptance and satisfaction) are not directly related to the learning outcomes. In addition, the mixed-methods design helps situate these findings by allowing quantitative indicators of acceptance to be interpreted alongside students' qualitative reflections, rather than in isolation.

Although the overall attitude was positive, this study emphasizes that technology acceptance encompasses more than emotional responses or user experiences [29]. It may also involve anticipating actions that enhance the effective use of new technologies [28, 29]. From this perspective, the findings suggest that technological tools in education can foster preparedness for future innovations beyond the immediate context of first-aid training. Students expressed meaningful ideas about integrating 3D technology into their professional practice, such as using it for patient education. While nurses' attitudes toward technology are generally positive and open[47], research indicates that preparedness for technological solutions could be improved[48].

Students described both educational and work-related opportunities for 3D technology. For example, they suggested that learning outcomes could improve with its use, particularly in anatomy instruction—a finding supported by previous studies[23, 44]. Although this research did not measure specific learning outcomes, students' perspectives represent an important element of the learning process aimed at positive results[49]. The exploratory quantitative results should therefore be understood as complementary to these qualitative insights, offering structured but preliminary indications rather than precise estimates of change.

Interestingly, students noted that using diverse 3D tools in education could enhance their future job profiles and readiness for multiple tasks. However, survey results showed no significant increase in the categories of "job relevance" and "image". This discrepancy between qualitative and quantitative findings may reflect the novelty of 3D technology or the ease of sharing ideas in group discussions. Alternatively, students may perceive 3D technology as professionally useful (perceived usefulness) without viewing it as a factor that enhances personal status (image). Such differences illustrate the value of a convergent mixed-methods approach, where inconsistent results across strands can signal meaningful nuances in students' perceptions.

Both qualitative and quantitative data indicated that students found 3D technology easy to use. The survey category "perceived ease of use" showed a significant increase in technology acceptance, supported by the qualitative theme "Preparedness for future technological solutions." While some studies identify 3D technology as a barrier when its use is complex[50, 51], the present findings are noteworthy because students successfully engaged with non-traditional tools in a mandatory course and considered them easy to use. Teachers, however, may perceive challenges related to instructional logistics, such as time requirements[52]. Yet, if students can manage technology with minimal experience, should teachers view their own technological competence as a barrier[53]?

Despite these promising results, students also reported challenges in applying 3D technology. Although most found it easy to use, prior research highlights various technological difficulties[46, 54]. In this study, as in others[55], some students experienced symptoms of virtual reality sickness—such as nausea and dizziness—linked to 3D environments[56]. While this study did not specify which technology caused these symptoms or their prevalence, the findings underscore the seriousness of this issue[56].

The Technology Acceptance Model (TAM) was applied in both surveys (TAM2) and as the framework for focus group interviews[29]. TAM has been validated across diverse educational contexts[30], which may reduce context dependency and enhance the generalizability of results beyond Finland. In this study, TAM proved flexible enough to accommodate different technological solutions, as reflected in the broad meaning units used in qualitative analysis. A narrower theoretical framework might have limited the depth of analysis.

Overall, this study demonstrates that integrating 3D technology into a first-aid course can promote technology acceptance from multiple perspectives. Both quantitative and qualitative findings support this conclusion, although the study is qualitatively dominant. Previous research has linked individual 3D technologies, such as 3D printing, to positive developments in technology acceptance[19, 57]. From this study's standpoint, teachers could foster greater technology acceptance by incorporating a variety of technological tools into their teaching. This approach may broaden educators' perspectives and encourage more innovative practices in vocational education.

Limitations

The first limitation concerns the sample, which is context-dependent. The educational system for practical nursing students in Finland differs from that of other countries, and the sample size—particularly for the survey—is relatively small. Consequently, the survey results should be considered indicative rather than generalizable. Furthermore, variations in practical nursing education internationally may require careful interpretation of these findings.

The second limitation is that this study does not focus on a specific 3D technological tool but rather addresses the concept as a whole. This approach may influence the results, as the impact of individual tools can vary significantly.

Third, the study is qualitatively dominant, and this has important implications for interpreting the findings. While quantitative data were included to provide supportive evidence, they should not be viewed as the primary basis for conclusions. The self-reported survey results, combined with the novelty value of 3D technology, may have contributed to the predominantly positive orientation of the findings. Therefore, any numerical outcomes—such as descriptive statistics or significance tests—must be interpreted with caution and in light of the qualitative insights that form the core of this research. Also, effect sizes were not reported because the quantitative strand was exploratory and descriptive within a qualitatively dominant mixed-methods design. This approach prioritized integration of qualitative and quantitative insights consistent with mixed-methods principles [58].

Finally, demographic data were not collected, as this was deemed irrelevant during the planning phase. However, factors such as age or socioeconomic background could influence technological attitudes, making this an important limitation.

5. Conclusions

Students identified multiple aspects of 3D technology that could support their learning, professional development, and future roles. However, technology acceptance should not become the primary goal of instruction. Healthcare educators must critically evaluate the pedagogical potential of 3D technology and consider using structured models—such as TAM—to design more comprehensive teaching strategies.

The novelty of this study was that it was conducted within practical nursing education, which emphasizes the need for research concerning technology acceptance at the level of vocational education and training. In the future, enhanced knowledge and competence in utilizing 3D technology may enable educators to assess students' technology acceptance more effectively. Further research is needed to determine the actual impact of 3D technology on technology acceptance among healthcare students with experimental studies. Longitudinal studies would be particularly valuable to explore the long-term effects of technology acceptance and its relationship to career development among practical nursing graduates.

Supplementary Materials

The supporting information can be downloaded at https://journals.niepublish.com/public/IPT-329-Supplementary-Materials.zip.

Author Contributions

M.A.: conceptualization, data curation, formal analysis, investigation, methodology, writing original draft, writing—reviewing, editing; M.V.: supervision, project administration, writing—reviewing, editing; H.N.: investigation, resources; S.K.: investigation, resources; C.S.-L.: project administration, writing—reviewing, editing; K.A.: software, data curation; L.S.: supervision, project administration, writing—reviewing, editing. All authors have read and agreed to the published version of the manuscript.

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Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

Data Availability Statement

Data are available from the first author upon reasonable request.

Conflicts of Interest

The authors declare no conflict of interest.

AI Use Statement

Microsoft Co-Pilot has been used in the proofreading of "introduction", "population and sample", "discussion", and "limitation". After the proofreading, the text has been carefully checked by the researcher group (M.A. and K.A.). The authors take full responsibility for the accuracy and originality of the final manuscript.

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